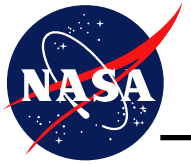
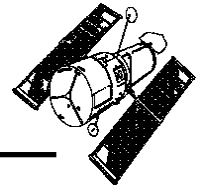


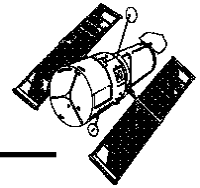
HST Two Gyro Science Overview



Agenda

- Organization
- Why?
- Overview
- Implementation
- Science Program Impacts
- Potential Operational Impacts
- Challenges
- Accomplishments
- Milestones

Two Gyro Science (TGS) Organization



TGS Working Group Coordination
Co-Chair: Larry Dunham
Co-Chair: Mike Prior

Pointing Control System (PCS)

PCS Working Group

- Algorithm Analysis, Design, Performance

Flight Software (FSW)

On-Board Attitude Determination (OBAD) Working Group

- On-Board MAP Design

Space Telescope Science Institute (STSCI)

- Visibility/CVZ Analysis
- SI Image Assessment

Consultants
Code 590: Landis Markley,
Mike Femiano
Greg Andersen
Hugh Dougherty

- Independent Review of PCS Design

Instrumentation & Communications (I&C)

- Comm Impact Assessment

Optical Telescope Assembly (OTA)

- Observation Scenarios

Safing

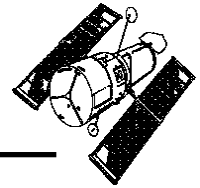
Safing Working Group

- Safing System Assessment

Sensor and Calibration (SAC)

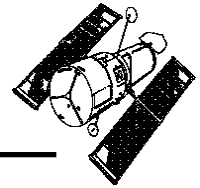
- SAC S/W Impacts

Co-Chair Role and Responsibilities



- Provide overall technical guidance to the development effort.
- Provide coordination for the resolution of major technical and operational issues.
- Co-Chair TGS Working Group.
- Provide regular briefings to upper level HST Project management.
- Develop and maintain TGS development schedule.
- Perform risk assessment.
- Perform technical analysis as needed.
  - Statistical analysis of potential loss of High Gain Antenna (HGA) communications due to degraded attitude events.

Why Develop a Two Gyro Science Mode?

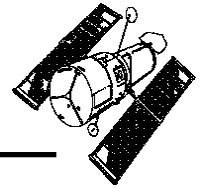


- The weak link in HST reliability has historically been the gyros

- HST has 6 gyros on board and currently needs three to perform science
  - In 1991, a new gyro-less Sun-Point safemode was developed (Zero Gyro Sun Point - ZGSP)
  - During SM1, 4 gyros were replaced (2 failed, 1w/problems) (1993)
  - During SM3A, all 6 gyros were replaced (4 failed, 1 w/problems) (1999)

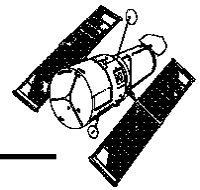
- Currently HST has two failed gyros and a third unit with anomalous behavior (FSW has been developed to compensate for the behavior)

Why Develop a Two Gyro Science Mode?



- There is a ~75% probability of having 3 working gyros prior to mid-2005 (former SM4 launch date).
  - Less than 50% by mid-2006.
- Mean Time Between Failure (MTBF) estimates predict about 15 months of operation would be possible with two gyros before another failure.
- Therefore TGS might also extend the life of HST science by 15 months at End of Life (EOL)
  - Other component failures may end life earlier than gyros.
  - When is projected EOL?…. Give me a date and I'll give you a probability.
- With no further servicing missions major focus will now be placed upon life extension measures (e.g. TGS, battery charge optimization, etc.)

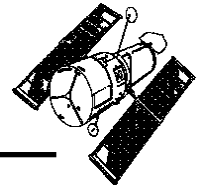
Mission Statement



The HST Project has therefore tasked us with developing a Two Gyro Science Mode

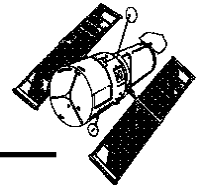
- **The Two Gyro Science (TGS) Mode is a means to provide spacecraft attitude control and slew capability, in the condition of only two remaining operational gyros, with sufficient accuracy in order to continue science gathering operations.**
- **It is a contingency mode primarily targeted for use in the event the HST is in a two gyro condition (prior to Servicing Mission 4). With all future SMs cancelled, there is now a high degree of certainty the mode will be utilized.**
- **It is also considered a degraded mode in that science operations will be capable of being performed but with less efficiency and flexibility compared to normal operations with 3 gyros.**
- **Particular classes of science observations will likely be heavily constrained or not possible.**

Overview



- Operations today use 3 gyros to provide rate control at all times. Attitude errors are limited to nominally a couple hundred arcseconds worst case after very large vehicle slews (typically 10-20 arcseconds).
- Onboard attitude updates using Fixed Head Star Tracker (FHST) data are done to get errors within Fine Guidance Sensor (FGS) search radius
- FGS data is used with gyro data to hold S/C position during science.
- With only 2 gyros and Magnetic Sensing System (MSS) data we may start with degrees of attitude error each orbit
- The FHST and/or FGS data are needed to control the rates as well as correct the attitude

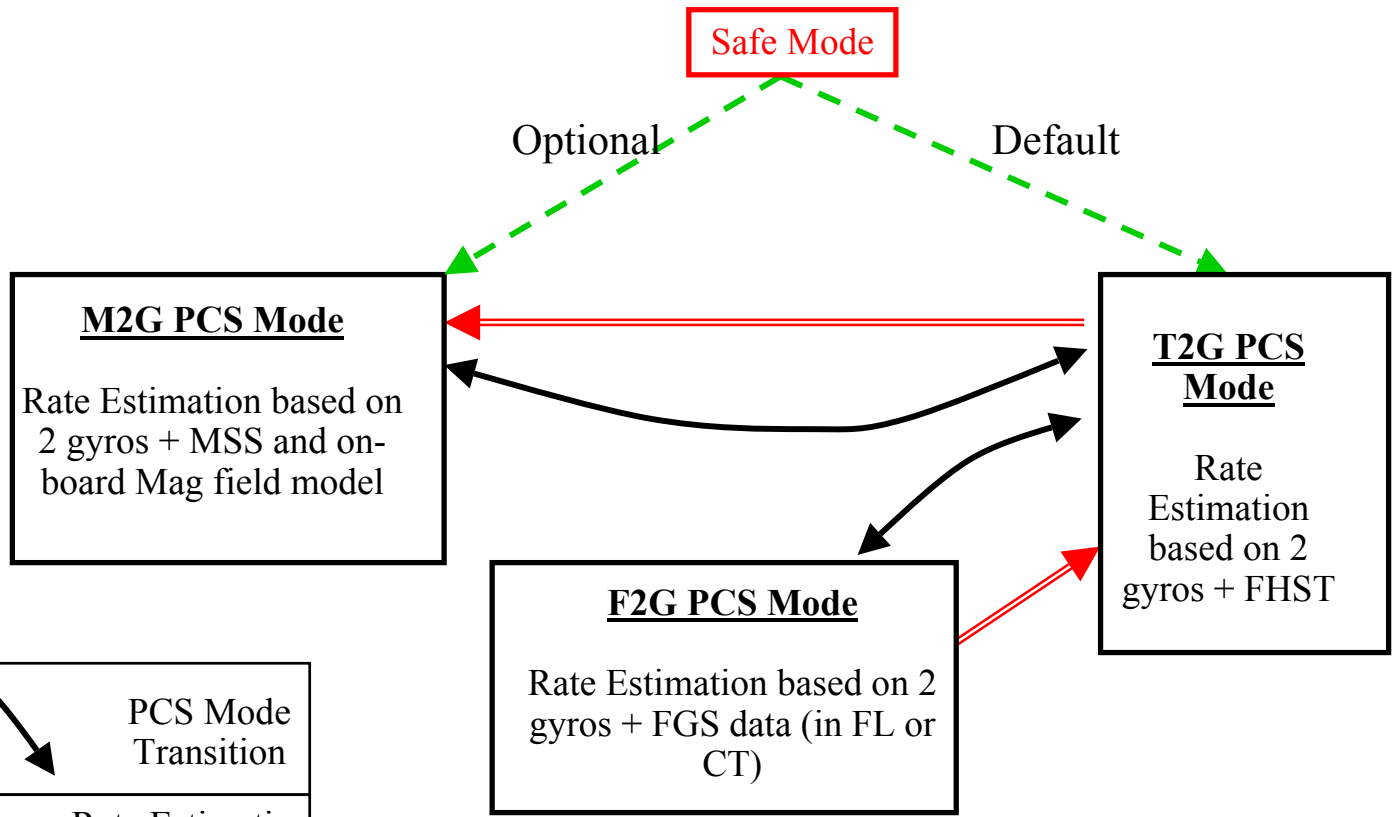
Overview



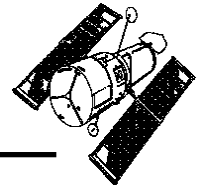
- **Three Operational Modes**
  - **MSS and 2 Gyros (M2G) - compares MSS output to Magnetic Field model to control attitude and rates with errors required to be less than 10 degrees. Supports Vehicle Maneuvers.**
  - **FHST and 2 Gyros (T2G) - requires one tracker to be visible to use FHST data and gyros to control rates. On Board Attitude Determination (OBAD) using FHST map data from 2 FHST units will bring attitude error within FGS search radius**
  - **FGS and 2 Gyros - (F2G) - requires FGS visibility to use FGS data and gyros to control rates and attitude to allow for science.**

- **Science Performance Requirement:**
  - **Jitter is required to be less than 30 milliarcseconds in the V2-V3 plane along the semi-major axis (60 second RMS, 1 sigma value).**
  - **Current 3 gyro performance is well within 7 milliarcseconds requirement (60 sec RMS).**

PCS Modes Overview

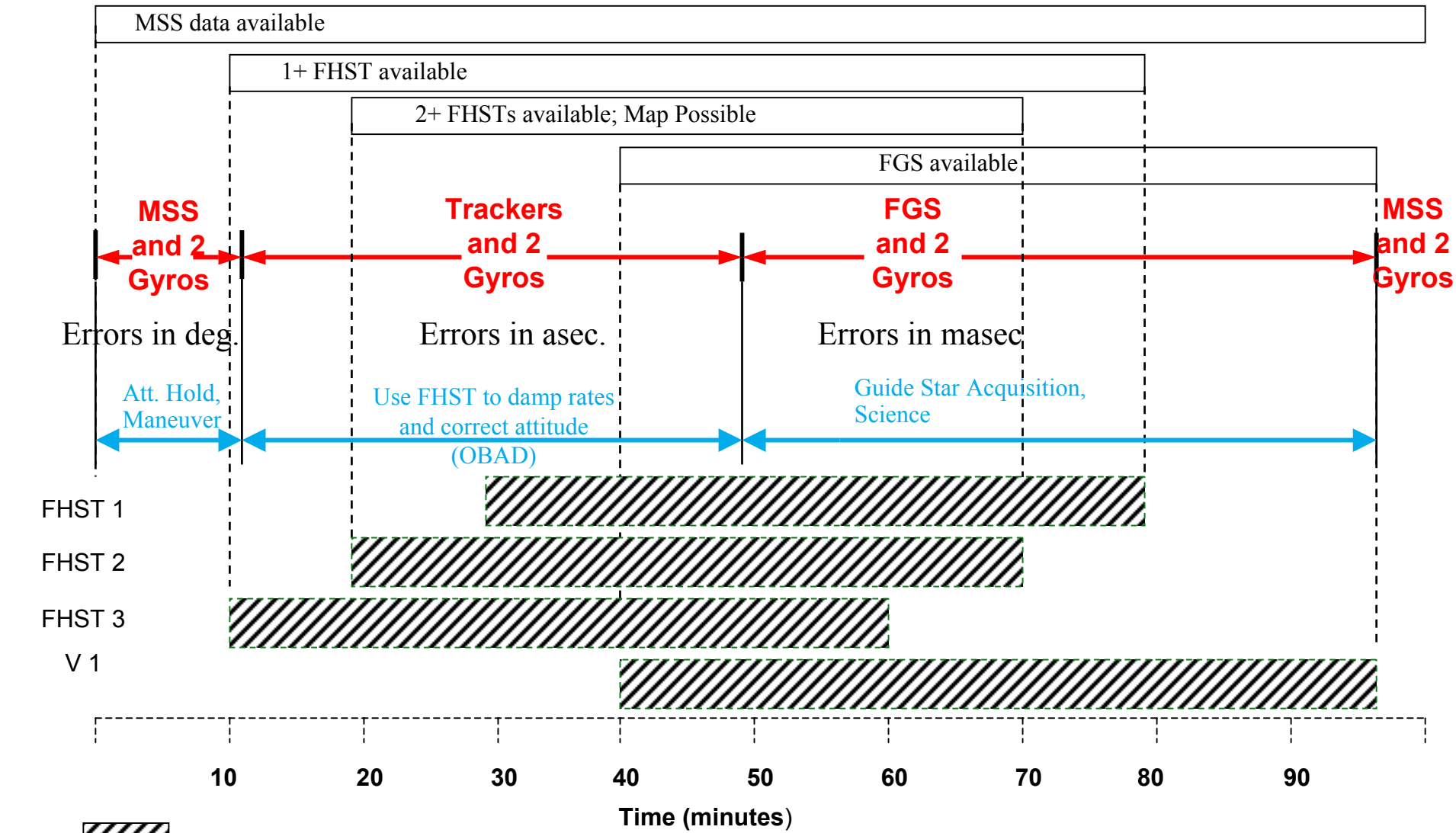


FSW Overview

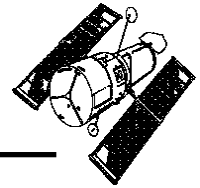


- **Current PCS Design is a PID (Proportional, Integral, Derivative) controller with an FGS (and FHST) observer to Provide Fine Pointing Control using a combination of sensors and actuators.**
- **TGS uses basic PCS System Design, but augmented for missing Gyro.**
- **On-Board Attitude Determination (OBAD) calculates attitude error using FHST and OBAD software.**
  - **Implements the attitude determination process in the 486 that is currently performed on the ground by the Sensors And Calibration group (SAC).**
  - **Generates updated cmd quaternion for correcting attitude error.**
  - **Newest and most complex FSW component.**
- **Extensive use of preview capability to exercise code and monitor results without active control.**
  - **To be used during on-orbit testing.**

Orbital Overview



Implementation

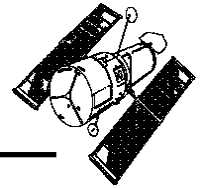


- **Development schedule includes 3 On-Orbit tests.**

- **Initial use would be limited to CVZ (Continuous View Zone)**
  - **Offers highest probability of continued science productivity while addressing any issues found in IOC**
  - **Allows for assessment of mode performance, timing, and attitude correction capabilities for incorporation into scheduling system**
  - **Will support limited full-sky science through reworked science visits and manual scheduling**

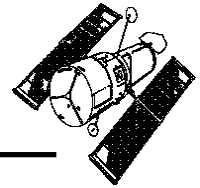
- **Then extend use to regions outside the CVZ for which FHST visibility adequately precedes and overlaps target visibility (all sky capability with reduced visibility windows)**

Impact on the HST Science program



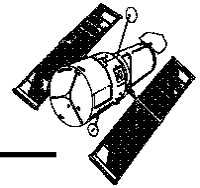
- Jitter performance in Two Gyro Science mode may not support all current science programs
  - Smallest aperture, highest spatial resolution programs may be affected (relatively small part of total program)
  - Potential restrictions will be better characterized after hi-fidelity PCS simulations and on-orbit tests
- Schedulability impacts on science program
  - Longer Guide Star acquisition times
    - » Currently takes ~ 6.1 minutes during V1 visibility period
    - » Will take ~ 10 minutes (tbr) in Two Gyro mode
  - No Guide Star re-acquisitions, must do full acquisitions
    - » ~ 10 minutes (tbr) vs. 5 minutes
  - Much more difficult FHST scheduling requirements
  - Large attitude errors in M2G mode may force large increase in Solar Avoidance Zone and substantially reduced target availability

Impact on the HST Science program



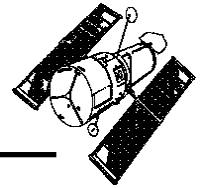
- **Current cycle Long-Range observing plan will be totally disrupted at entry into Two Gyro Science mode**
  - **Most current visits will not schedule due to longer GS acquisition times (simple problem)**
    - » **Packed orbits may not accommodate extra duration**
  - **Most current visits will not schedule due to FHST requirements (difficult problem)**
    - » **Some scheduling requirements imply a time of year and roll angle restriction for visits**
    - » **These will conflict with FHST visibility requirements**
- **Net result is the current science program at the time of Two Gyro mode entry will be largely unusable in the state it is in.**

Impact on Spacecraft Operations



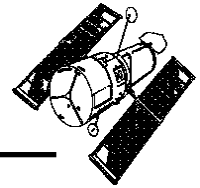
- **Less Tolerant of FGS and FHST failures**
- **FGS Loss of Lock (LOL)**
- **Unfavorable Magnetic Field Alignments result in large attitude errors in M2G mode**
  - **2^0-10^0 versus arcseconds.**
  - **Will result in occasional HGA comm dropouts.**
  - **May severely impact science target availability due to more restrictive solar avoidance zone.**

Major Challenges



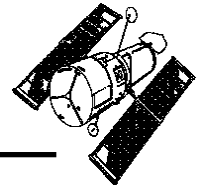
- Incorporation of operational constraints into scheduling system touches most major components and will be performed in two phases.
- TGS science program must be designed accounting for operational and scheduling limitations.
  - Transition from 3 gyro to 2 gyro science operations will need to be carefully managed.
- Design of M2G mode to reduce attitude errors has taken recent priority due to its large potential impact on science target availability.
- Risk assessment of FGS fine lock walk down requires additional FGS HW testing and early design of F2G mode.
- The development of TGS capability affects most aspects of the operations thus requiring a large coordination effort.

Accomplishments



- **Held Ops Concept/Requirements Review and PDR.**
  - **System level and scheduling system requirements defined.**
- **Completed first design iteration of M2G mode.**
  - **Redesign efforts to reduce error are underway.**
- **Completed initial design work for T2G mode.**
  - **Coding to start in Feb.**
- **Completed significant part of FGS fine lock walkdown risk assessment.**
  - **FGS HW testing and PCS simulation of jitter environment completed.**
  - **Remaining portion will be completed in March with the initial FGS design.**

Milestones



• System Level SRR/OCR	September 4, 2003
• System Level PDR	November 1, 2003
• Scheduling System Design Review	February 8, 2004
• System Level CDR	March 15, 2004
• M2G Mode On-Orbit Test	July 24, 2004
• T2G Mode On-Orbit Test	November 11, 2004
• F2G Mode On-Orbit Test	February 18, 2005
• Operations Readiness Review	April 2005